(12) UK Patent Application (19) GB (11) 2 077 532 A

(21) Application No 8115885
(22) Date of filing 22 May 1981
(30) Priority data
(31) 80/18283
(32) 4 Jun 1980
(33) United Kingdom (GB)
(43) Application published 16 Dec 1981
(51) INT CL³ H02H 3/347
(52) Domestic classification H2K 301 360 463 480 595 771 FA
(56) Documents cited
GB 2012505A
GB 354296
Proceedings of the Institution of Electrical Engineers Vol. 126, No. 2 (Feb 1979) pp. 149-151
(58) Field of search H2K

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(54) Earth l akag protection arrangement

(57) An earth leakage protection arrangement for a feeder of a 3-phase resistively earthed electric power transmission system comprising a relay 5 responsive to the residual current in the feeder which operates an associated circuit breaker 23 when the residual current exceeds a predetermined value. The operation of the circuit breaker is prevented (7) unless the phase relation between the system zero sequence voltage and the feeder residual current lies in a predetermined range.

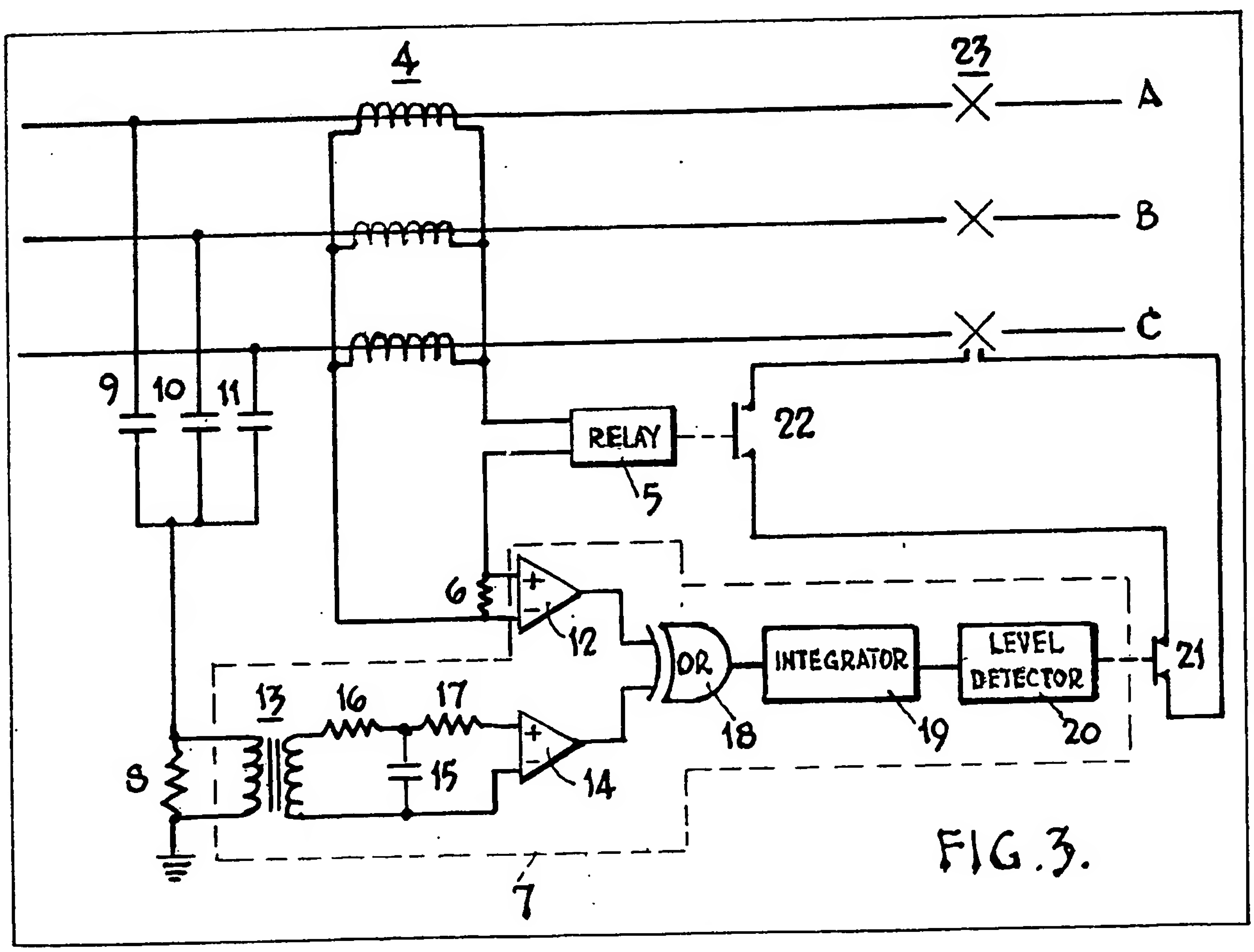

FIG. 3.

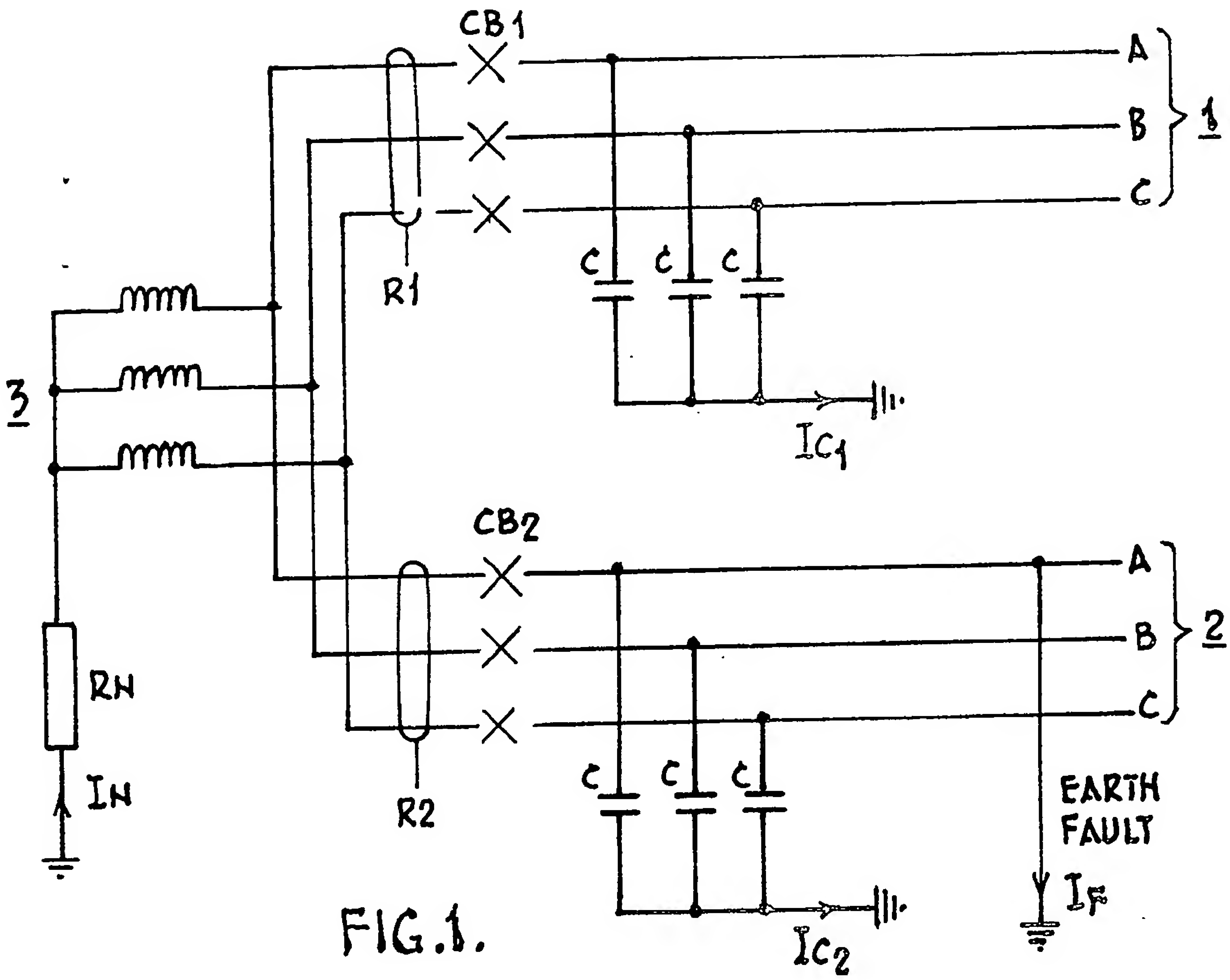

FIG.1.

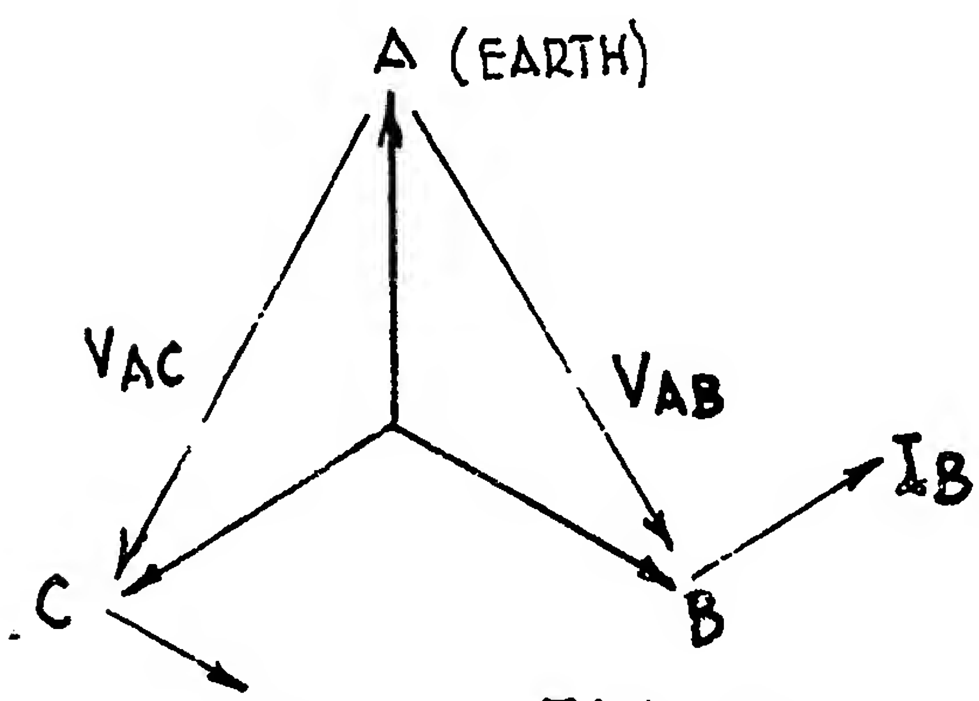

FIG.2A.

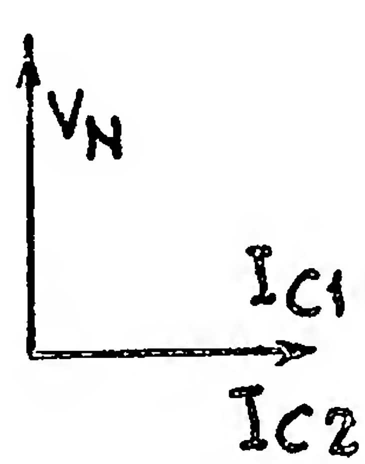

FIG.2B.

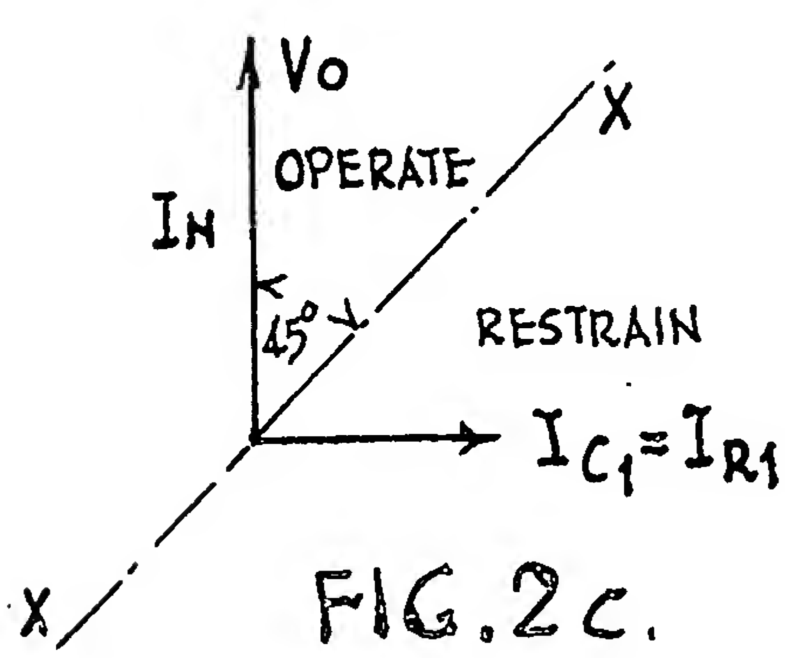

FIG.2C.

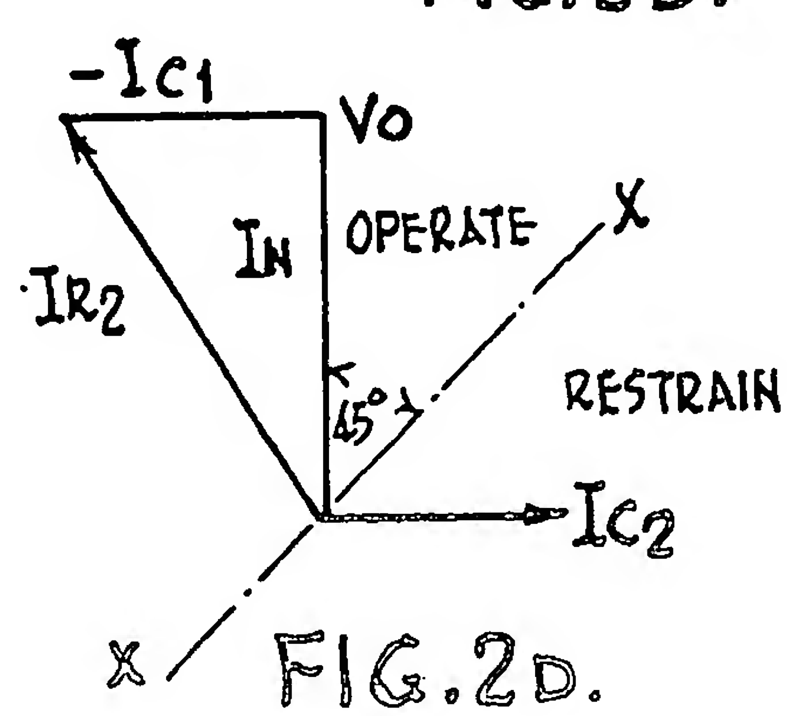

FIG.2D.

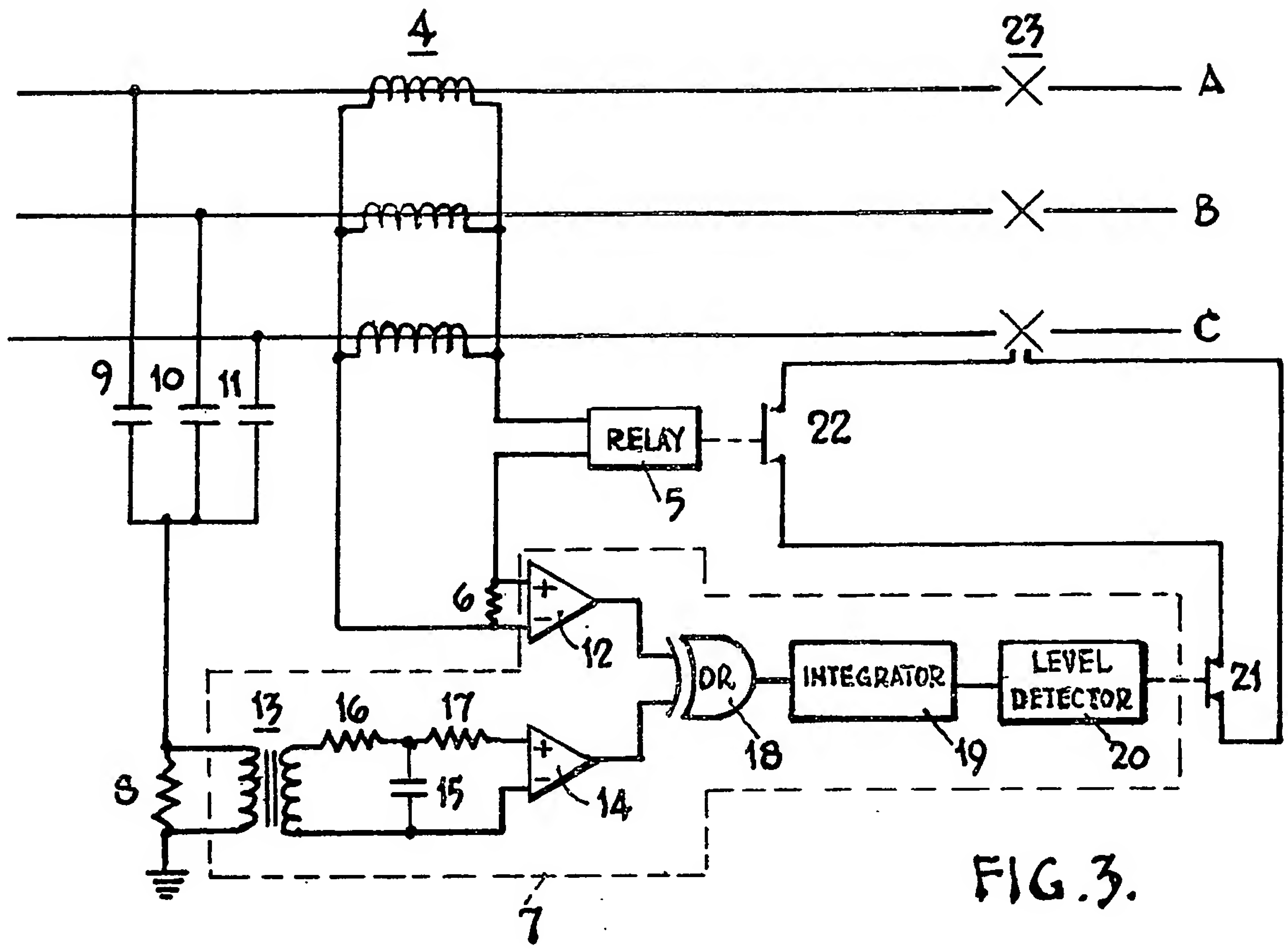
4
23
A
B
C
9
10
11
RELAY
5
22
6
12
OR
18
INTEGRATOR
19
LEVEL DETECTOR
20
21
13
16
17
15
14
8
7

FIG. 3.

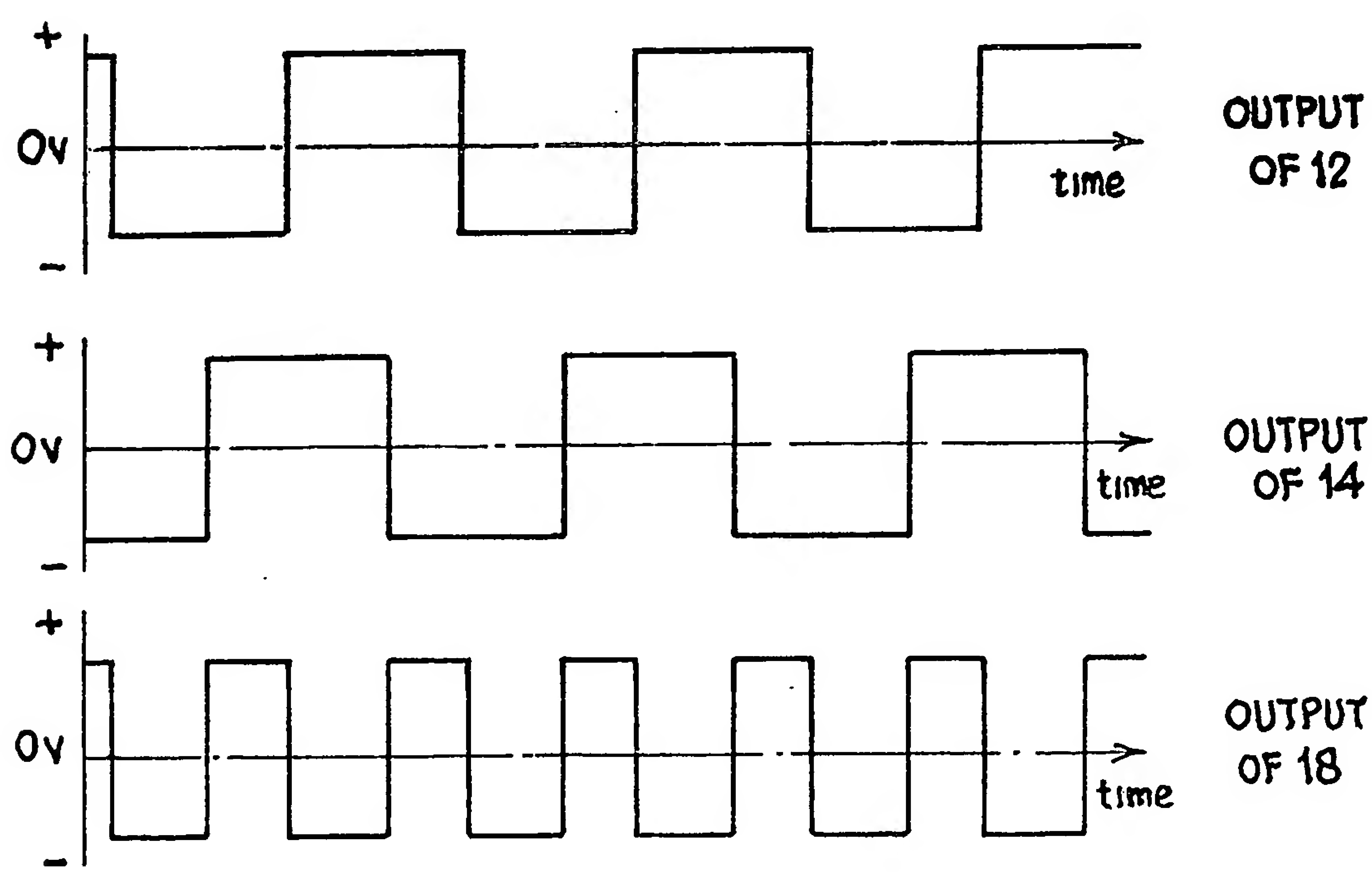
+
0v
-
time
OUTPUT OF 12
OUTPUT OF 14
OUTPUT OF 18

FIG. 4.

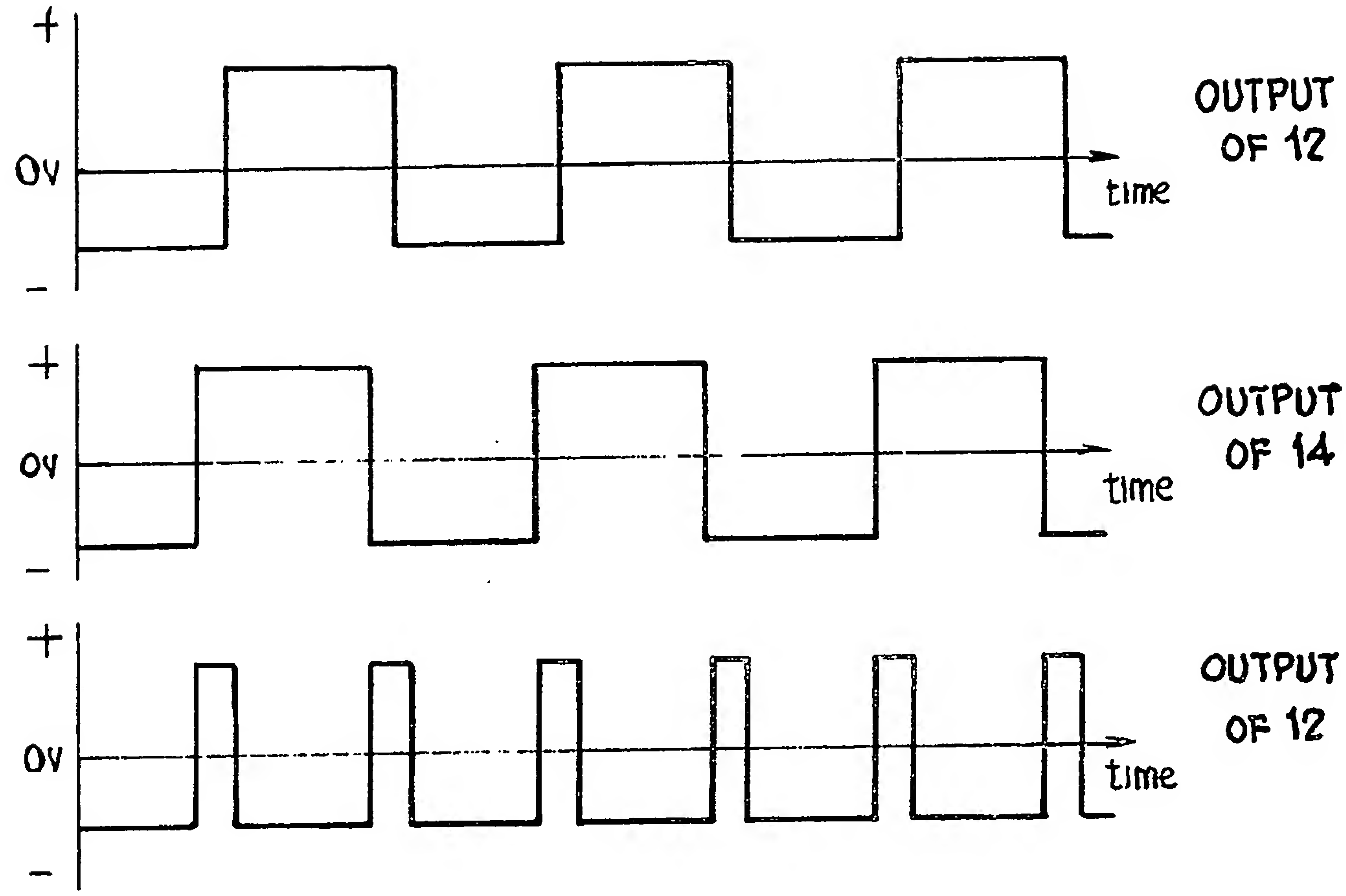
+
OV
−
time
OUTPUT OF 12
+
OV
−
time
OUTPUT OF 14
+
OV
−
time
OUTPUT OF 12

FIG. 5.

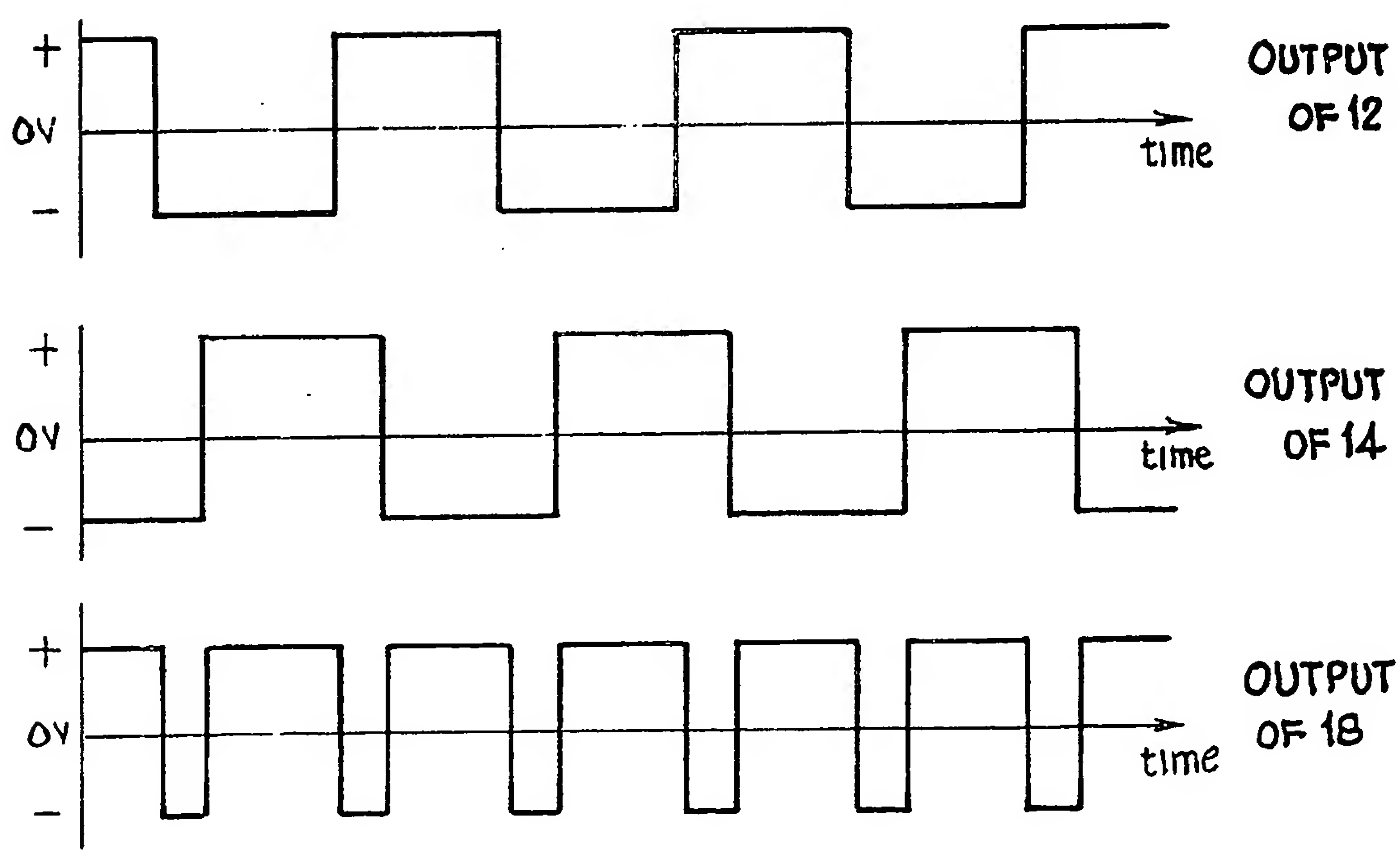
+
OV
−
time
OUTPUT OF 12
+
OV
−
time
OUTPUT OF 14
+
OV
−
time
OUTPUT OF 18

FIG. 6.

SPECIFICATION

Earth leakage pr tecti n arrangement

This invention relates to earth leakage protection for electric power distribution systems.

The invention relates particularly to earth leakage protection for polyphase resistively earthed electric power distribution systems.

Such protection is conventionally obtained by providing each feeder in the system with a relay responsive to the residual current in that feeder and arranged to operate an associated circuit breaker when the residual current exceeds a predetermined value. However, with such an arrangement, if the system conductors are individually screened and the screens are earthed, e.g. for safety reasons, an earth fault on one feeder can cause operation of the earth leakage protection relays on adjacent healthy feeders.

It is an object of the present invention to provide an earth leakage protection arrangement wherein this problem is overcome.

According to the present invention an earth leakage protection arrangement for a feeder of a polyphase resistively earthed electric power transmission system comprises a relay responsive to the residual current in the feeder and arranged to operate an associated circuit breaker when the residual current exceeds a predetermined value, and means for preventing operation of the circuit breaker unless the phase relation between the system zero sequence voltage and the feeder residual current lies in a predetermined range.

In a preferred arrangement for use in a three-phase electric power transmission system, said means prevents the operation of the circuit breaker unless the feeder residual current lags the system zero sequence voltage by less than 45° or leads it by less than 135°.

The invention will now be further explained, and one arrangement in accordance with the invention described by way of example, with reference to the accompanying drawings in which:—

Figure 1 is a schematic diagram illustrating a 3-phase resistively earthed electric power distribution system employing individually screened conductors;

Figure 2A to 2D are vector diagrams illustrating conditions in the system under an earth fault condition;

Figure 3 is a circuit diagram of one arrangement in accordance with the invention; and

Figures 4, 5 and 6 illustrate waveforms appearing at various points in the circuit of Figure 4 in operation.

The problem which the present invention solves will now be explained in greater detail with reference to Figures 1 and 2.

Figure 1 shows an electric power distribution system comprising two feeders 1 and 2 supplied from the star-connected secondary 3 of a distribution transformer whose star-point is earthed via a resistor R_N. Each feeder is provided with an earth leakage protection arrangement comprising a relay R_1 or R_2 responsive to the residual current on the associated feeder, and an associated circuit breaker CB1 or CB2.

The conductors A, B, C in the system are individually screened and the screens earthed, the capacitances between the conductors and their associated screens being represented in Figure 1 by capacitances C.

Under normal conditions the currents in the capacitances C associated with each feeder are equal and at 120° phase displacements so that the total capacitance currents I_{C1} and I_{C2} of the two feeders are both zero.

When an earth fault occurs on a conductor of one feeder, for example, conductor A of feeder 2 as shown in Figure 1, the capacitance associated with conductor A of each feeder is short circuited and the current in that capacitance becomes zero. However, as illustrated in Figure 2A, a current I_B flows in the capacitor associated with conductor B of each feeder which leads the conductor-to-conductor voltage V_{AB} by 90°. Similarly, a current I_C flows in the capacitor associated with conductor C of each feeder which leads the conductor-to-conductor voltage V_{AC} by 90°. Hence, as shown in Figure 2B, the currents I_{C1} and I_{C2} both become finite and lag the voltage V_N across the earthing resistor R_N by 90°, V_N being the pre-fault voltage on the faulted conductor A.

The residual currents I_{R1} and I_{R2} to which the relays R1 and R2 are responsive are given by the expressions

$$I_{R1} = I_{C1} \qquad \text{(i)}$$
$$I_{R2} = I_{C2} + I_F \qquad \text{(ii)}$$

where I_F is the current in the earth fault.

Hence on occurrence of an earth fault on the feeder 2 in the system of Figure 1 the relay R_1 may respond to current I_{C1} to operate circuit breaker CB1 and cut-off the supply to the healthy feeder 1.

The supply to further healthy feeders (not shown) connected to transformer secondary 3 may be similarly unnecessarily interrupted.

In accordance with the invention, this difficulty is solved by controlling the operation of the circuit breakers CB1 and CB2 in dependence on the phase relations between the relay currents I_{R1} and I_{R2} and the system zero sequence voltage Vo.

Since the relay current I_{R1} is the total capacitance current I_{C1} of feeder 1, it is apparent from Figure 2B that the relay current I_{R1} lags the voltage V_N by 90°. Hence, since the current I_N in resistor R_N is in phase with the voltage V_N across resistor R_N, and I_N is in phase with the zero sequence voltage Vo, the relay current I_{R1} lags the zero sequence voltage Vo by 90°, as shown in Figure 2C.

The phase of relay current I_{R2} relative to the zero sequence voltage Vo may be deduced as follows:

From Figure 1 it is clear that

$$I_N = I_{C1} + I_{C2} + I_F \qquad \text{(iii)}$$

and from equations (i) and (ii) it can be deduced that

$$I_{R2} = I_N - I_{C1} \qquad \text{(iv)}$$

Hence, as shown in Figure 2D, the relay current I_{R2} leads the zero sequence voltage Vo by an amount depending on the amplitude of capacitance current I_{C1}.

Tripping of a circuit breaker of a healthy feeder due to an earth fault on an adjacent feeder can thus

be prevented by inhibiting operation of the circuit break r unless the phase relation between the relay current and system zero sequence voltage is such as to indicate that the fault is on the feeder associated with that circuit breaker.

The required inhibition is suitably eff cted under control of a phase comparator with a boundary along line X-X in Figures 2C and 2D at 45° to the phase of zero sequence voltage Vo, the associated circuit breaker being allowed to operate or being restrained according to which side of the line X-X the relay current vector lies.

Figure 3 shows in block schematic form one earth l akage protection arrangement in accordance with the invention.

In this arrangement, the output of a core balance current transformer 4 is applied in series to the operating coil of a relay 5 and a resistor 6 connected across one input of a phase comparator 7. The other input of the phase comparator 7 is derived from across a resistor 8 one end of which is earthed and the other end of which is connected to the conductors A, B and C of the associated feeder via respective capacitors 9, 10 and 11.

In the comparator 7 the input derived from across resistor 6 is applied to a first differential amplifier 12. The input derived from across the resistor 8 is isolated by a voltage transformer 13 and applied to the input of a second differential amplifier 14 via a network comprising a capacitor 15 and two resistors 16 and 17 to phase shift the input by 45° in the lagging direction.

The outputs of the amplifiers 12 and 14 are applied to respective inputs of an exclusive OR gate 18 whose output is fed to a short time constant integrator 19. The output of the integrator 19 is applied to a level detector 20 whose output controls the operation of a contactor 21.

In operation the voltage across the secondary of transformer 13 leads the system zero sequence voltage by 90°. Thus the voltage applied to amplifier 14 leads the zero sequence voltage by 45° and hence leads the line X-X in Figures 2C and 2D by 90°. The amplifier 14 operates as a squarer to provide a square wave output leading the zero sequence voltage by 45°.

The amplifier 12 also operates as a squarer to provide a square wave output in phase with the current in relay 5.

Referring now to Figure 4, when the relay current lags the zero sequence voltage by 45°, or leads it by 135° i.e. lies on the line X-X in Figures 2C and 2D, the outputs of amplifiers 12 and 14 are 90° out of phase and the output of gate 18 has a mark-space ratio of 1:1. Hence, the output of integrator alternates about zero.

As illustrated in Figures 5 and 6, when the phase of the relay current changes so that th relay current lies to one side or the oth r of the line X-X, then the mark space ratio of the output of gate 18 changes in one sense or the other so that the integrator output rapidly increases in one sense or the other. The level detector is responsive to the output of the integrator to operate the contactor 21 so that the contactor 21 is closed when the integrator output exceeds a given value in the sense corresponding to the relay current lying on the operate side of the line X-X. Thus the contactor 21 closes only when the relay current leads the zero sequence voltage by less than 135° or lags it by less than 45° and remains open when the relay current leads the zero sequence voltage by more than 135° or lags it by more than 45°.

Thus the contactor 21 closes only when ther is an earth fault on the associated feeder.

The contactor 21 is connected in series with a contactor 22 closed by the relay 5 when the relay current exceeds a predetermined value, the contactors 21, and 22 controlling the supply of operating current to a circuit breaker 23 arranged to disconnect the feeder and clear the fault when operated.

While the arrangement described by way of example is for a three phase system it will be appreciated that the arrangement can be readily adapted for use in a polyphase electric power distribution system having a different number of phases by appropriate choice of the line X-X.

CLAIMS

1. An earth leakage protection arrangement for a feeder of a polyphase resistively earthed electric power transmission system comprising: a relay responsive to the residual current in the feeder and arranged to operate an associated circuit breaker when the residual current exceeds a predetermined value, and means for preventing operation of the circuit breaker unless the phase relation between the system zero sequence voltage and the feeder residual current lies in a predetermined range.

2. An arrangement according to Claim 1 for use in a three-phase electric power transmission system in which said means prevents the operation of the circuit breaker unless the feeder residual current lags the system zero sequence voltage by less than 45° or leads it by less than 135°.

3. An arrangement according to Claim 2 wherein said means comprises: an exclusive OR gate having a first input having the phase of the feeder residual current, and a second input having a phase leading the system zero sequence voltage by 45°; an integrator responsive to the output of the gate; and a level detector responsive to the output of the integrator to prevent operation of the circuit breaker unless the output of the integrator exceeds a predetermined value in a given sense.

4. An arrangement according to Claim 3 wherein said first and second inputs comprise signals of square waveforms.

5. An arrangement according to Claim 3 or Claim 4 wherein said second signal is derived by way of a phase shifting network from acrpss a resistance connected to the lines of the feeder via respective capacitances.

6. An earth leakage protection arrangement substantially as hereinbefore described with reference to Figure 3 of the accompanying drawings.

7. An electric power transmission system including at least two feeders the conductors of which are individually screened and earthed and incorporating an earth leakage protection arrangement for each feeder in accordance with any one of the preceding claims.

Printed for Her Majesty's Stationery Office by The Tweeddale Press Ltd., Berwick-upon-Tweed, 1981.
Published at the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.